भारतीय मानक
Indian Standard

IS 6416 : 2022
[*Amalgamating* IS 6416 *and* IS 8795]

स्टील की केस-डेप्थ को मापने के तरीके

(दूसरा पुनरीक्षण)

Methods for Measuring Case Depth of Steel

(Second Revision)

ICS 77.040.99

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FOREWORD

This Indian Standard (Second Revision) was adopted by the Bureau of Indian Standards, after the draft finalized by the Metallography and Heat-Treatment Sectional Committee had been approved by the Metallurgical Engineering Division Council.

This standard was first published in 1971. In the current revision, method for determining case depth of carburized steel using fracture test have been included which were previously covered separately in IS 8795 : 1978 'Method for determining case depth of carburized steel by fracture test', the Committee decided to merge IS 6416 : 1988 Methods for measuring case depth of steel (*first revision*) and IS 8795 : 1978 Method for determining case depth of carburized steel by fracture test as IS 6416 'Methods for measuring case depth of steel'.

In this revision Clause on 'Fracture Method' have been added from IS 8795.

The composition of the Committee and the Panel responsible for the formulation of this standard is given at Annex B.

For the purpose of whether a particular requirement of this standard is complied with the final value, observed or calculated, expressing the result of a test or analysis shall be rounded off in accordance with IS 2 : 2022 'Rules for rounding off numerical values (*second revision*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

METHODS FOR MEASURING CASE DEPTH OF STEEL

(Second Revision)

1 SCOPE

This standard prescribes the following five methods of measuring case depth (CD) of steel hardened by carburizing, nitriding, carbonitriding, cyaniding or induction and flame hardening (applicable methods are indicated in Table 1):

a) Hardness method,
b) Chemical method,
c) Macrostructure method,
d) Microscopic method; and
e) Fracture method (for routine process control).

2 REFERENCES

The following standards contain provisions which through in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below:

IS No.	*Title*
228 (relevant parts)	Methods for chemical analysis steels
1501 (Part 1) : 2020/ ISO 6507-1 : 2018	Metallic materials — Vickers hardness test: Part 1 Test method (*fifth revision*)
1586 (Part 1) : 2018/ ISO 6508-1 : 2016	Metallic materials — Rockwell hardness test: Part 1 Test method (*fifth revision*)
1956 (relevant parts)	Glossary of terms relating to iron and steel

3 TERMINOLOGY

For the purpose of this standard, definitions given in IS 1956 and the following shall apply.

3.1 Effective Case Depth — It is the perpendicular distance from the surface to that point of the core of the piece at which hardness is equal to the values shown below:

Type of Steel Steel with Carbon, Percent	HV	HRC	HRA	Treatment
0.28 to 0.32	350	35	68	Flame or induction hardened
0.33 to o.42	400	40	70	
0.43 to 0.52	450	45	73	
Over 0.53	500	50	76	
Case hardening steels	550	–	–	Carburized, and hardened and tempered
Nitriding and carbonitriding	Values to be mutually agreed upon			Nitrided and carbonitrided

3.2 Total Case Depth — It is the perpendicular distance from the surface to that point at which the change in chemical composition, hardness or microstructure of the case and core no longer can be distinguished.

4 SAMPLING

The number of test pieces to be used for testing and their selection shall be as agreed to between the contracting parties.

5 HARDNESS METHOD

5.1 Principle

This method consists of cutting the specimen at right angle to the hardened case, preparing the surface suitably for testing and making a hardness traverse on the case and core of the specimen.

5.2 This method is considered to be most accurate for measuring case depths and may be used as a referee and control method applicable to either specimens or parts.

5.3 Preparation of Surface to be Examined

The test specimen shall be cut at right angle to the hardened case and polished so as to permit correct measurement of hardness impressions. Care shall be taken in cutting to avoid heating that may affect the hardened surface.

5.4 Hardness Measurement

Hardness testers that produce small shallow indentations shall be used. Testers used to produce diamond pyramid or Knoop hardness numbers are recommended. The test load will be between 0·98 and 98·1 Newtons (0·1 and 10 kgf). Rockwell A or C scales produce a comparatively deeper indentation and these can be used in case of flame or induction hardened cases.

5.4.1 For Vickers hardness and Rockwell C scale hardness test, reference may be made to IS 1501 (Part 1) and IS 1586 (Part 1) respectively.

5.4.2 A hardness transition curve shall be drawn by measuring hardness on a few number of points along the straight lines at right angles to the plane as shown in Fig. 1 and measuring the distance of respective hardness indentations from the outer edge of hardened case. This distance can be measured on a calibration optical instrument, micrometer stage or by other suitable means. The hardness traverse should extend up to the core. The space between the measuring points on sample (l_2-l_1, l_3-l_2,l_4-l_3, etc, in Fig. 1) will not exceed 0.1 mm, in general. The space between adjacent indentations shall be not less than 2·5 times the diagonal length of indentations. The effective case depth or the total case depth shall be determined from the hardness transition curve.

6 CHEMICAL METHOD

6.1 This method is generally applicable only to carburized cases, but may be used for nitrided, cyanided or carbonitrided cases. The procedure consists in determining the carbon content (and nitrogen when applicable) at various depths below the surface of a test specimen. This method is considered the most accurate for measuring total case depth of carburized cases.

6.2 Specimen

Test specimens shall normally be of the same grade of steel as parts being carburized. Test specimen may be actual parts, rings or bars and should be straight or otherwise suitable for accurate machining of surface layers into chips for subsequent carbon analysis.

6.2.1 Test specimens shall be carburized with parts. Care should be exercised to avoid distortion and decarburization in cooling test specimens after carburizing. In **cases** where parts and test specimens are quenched after carburizing, such specimens shall be tempered at approximately 600-65 G °C and straightened to 0·04 mm maximum total indicator reading (TIR) before machining is attempted. The time at this temperature should be minimized to avoid excessive carbon diffusion.

6.2.2 Test specimens must have clean surfaces and shall be machined dry in increments of predetermined depth. The analysis of machined chips will then accurately reveal the depth of carbon penetration. Chosen increments usually vary between 0.050 and 0.10 mm depending upon the accuracy desired and expected depth of case.

6.2.3 Chips from each increment shall be kept separate and analyzed individually for carbon content by an accepted method. Total case depth is considered to be the distance from the surface equivalent to the depth of the last increment of machining whose chips analyze to carbon content percent higher than that of the established carbon content of the core.

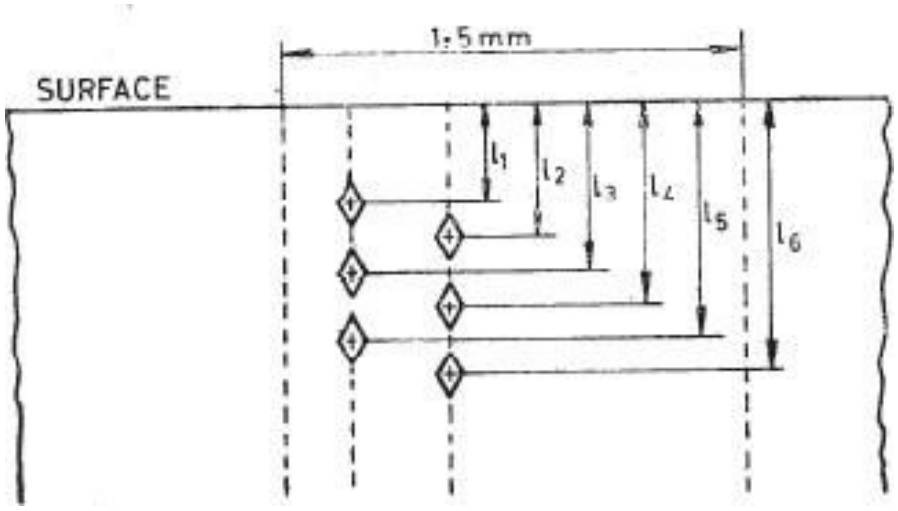

FIG. 1 ARRANGEMEIST FOR HARDNESS MEASUREMENT

6.3 Analysis

The chemical analysis of the metal shall be carried out in accordance with IS 228.

7 MACROSTRUCTURE METHOD

7.1 Macroscopic method of determination of case depth is recommended for routine process control, primarily because of short time required for determinations and minimum of specialized equipments and trained personnel needed. This method is mostly applied to hardened and carburized specimens.

7.2 The test consists of determining the depth of hardened surface under low magnification on the sectional surface of test specimen. A wide variety of etchants can be used successfully to enhance the contrast between case and core. The total case depth shall be determined by measuring the distance from the surface to the point showing a different coloration. Accuracy can be improved by correlation of macrostructure observed with other methods, such as hardness method.

7.3 Preparation of Surface to be Examined

The test specimens shall be cut or fractured perpendicular to the hardened surface. Following variations may be adopted depending upon the accuracy desired.

7.3.1 *Fracture*

Prepare product or sample by fracturing. Examine at a magnification not to exceed 20 x with no further preparation.

7.3.2 *Fracture and Etch*

Prepare product or sample by fracturing and then etching in 20 percent nitric acid in water for a time established to develop maximum contrast. Rinse in water and read while sample is still wet.

7.3.3 *Fracture and Rough Grind*

Prepare specimen by either fracturing or cutting and rough grinding. Etch in 10 percent nital for a period of time established to provide a sharp line of demarcation between case and core. Examine at magnification not to exceed 20 X and read all the darkened zone for approximate total case depth. Care shall be taken during the cutting and grinding to avoid any heating of the specimen.

7.3.4 *Fracture, Grind and Polish*

Prepare specimen by fracturing or cutting, grinding is no longer distinguishable. Through No. 000 or fine metallography emery paper, polish and etch in 5 percent nital for approximately one minute. Rinse in water and examine at a magnification not exceeding 20 x and read all the darkened zone. After correlation, effective case depth can be determined by reading from external surface of specimen to a select line of darkened zone.

8 MICROSCOPIC METHOD

8.1 The test consists in determining the depth of preparation. Hardened surface under a metallurgical microscope. In the case of nitride parts where depth is thin, this method is recommended.

8.2 Preparation of Surface to be Examined

The test specimen shall be cut perpendicular to the hardened surface and the cut face polished. Care shall be taken during cutting or polishing to avoid any heating of the specimen.

8.2.1 The test surface shall be etched in two to three percent nital or any other suitable reagent.

8.3 Magnification

The polished and etched specimen shall be examined any heating of the specimen. at 100 times magnification.

8.3.1 The total case depth is the distance from the surface to the point at which the change in structure is no longer distinguishable.

9 FRACTURE METHOD

9.1 This method of measuring case depth by fracture test is applicable for carburized steel for routine process control purposes. Recognizing the need for a quick shop-floor test, this standard has been prepared to provide a guide for procedure to be adopted for rapid determination of case- depth in carburized steels. However, this method shall not be used as a referee method.

9.2 Preparation of Surface to be Examined

Notched test bars (notched up to about half of diameter) with a diameter of at least five times the desired case-depth, of adequate length and made from the same batch of steel as the articles to be carburized, should be carburized with the work. As soon as the time specified for carburizing has elapsed, one test bar shall be withdrawn from the carburizing medium, quenched in water and fractured by a hammer.

9.3 The fractured surface should be etched in a solution of 20 percent nitric acid in water for a time established to develop maximum contrast between the core and the case and then rinsed in water. The width of the case shall then be measured by means of a fine-point divider and a graduated scale.

9.4 If required, a correlation may be established between the method described in **9.1** and the microscopic method of case-depth measurement as follows:

Pilot samples, selected from the batch of steel to be carburized, should be subjected to carburizing treatment. Samples should be quenched in water after withdrawing from the carburizing media. The quenched sample should be cut by a metallographic or other abrasive cut-off saw under coolant. The cut-off face, if necessary, should be polished on emery papers, and then etched in 3-5 percent Nital solution for 15-30 s. The carburized layer will become visible as greyish black skirt in the periphery. The width of the skirt should be measured with a graduated scale and a fine point divider and also by the microscopic method as described in **8**. The two sets of readings should be compared for establishing the correlation between the two methods of measurement.

10 DESIGNATION OF CASE DEPTH

10.1 The indication of case depth shall be made by the identification symbols given in Table 1.

10.2 The case depth shall be given in mm, measuring correct to one place of decimal, and be expressed in unit of 0.1 mm.

Examples

a) CDE 15 HV 1 effective case depth of 1’5 mm-measured by Vickers hardness test using 1 kg load.

b) CDT 25 HV 5 total case depth of 2’5 mm-measured by Vickers hardness test using 5 kg load.

c) CDT 22 Ma total case depth of 2’2 mm measured by macrostructure method.

d) IDE (400) 15 HV 5 induction hardened, effective case depth of 1·5 mm measured up to 400 HV from the surface using 5 kg load.

e) FDE (40) 25 HRC flame hardened, effective case depth of 2.5 mm-measured up to 40 HRC from the surface.

f) FDT 40 HV 5 flame hardened total case depth of 4.0 mm-measured by Vickers hardness testing using 5 kg load.

g) FDT 20 Ma flame hardened, total case depth of 2.0 mm-measured by the macrostructure method.

Table 1 Identification Symbols for Case Depth

(*Clauses* 1 *and* 10.1)

Case Depth	Hardness Method	Macrostructure Method	Microscopic Method	Chemical Method	Fracture Method
Carburized Total case depth	CDT_____HX*	CDTcMa	CDT_____Mi	CDT_____Ch	CDT_____Fr
Effective case depth Nitrided Total case depth	CDE()_____HX* NDT_____HX*	_____	_____ NDT_____Mi	_____ NDT_____Ch	_____
Carbonitrided Total case depth	CNDT_____HX*	_____	CNDT_____Mi	CNDT_____Ch	_____
Flame hardened Total depth of hardened surface Effective depth of hardened surface	FDT_____HX* FDE ()_____HX*	FDT_____Ma _____	FDT_____Mi _____	_____ _____	_____ _____
Induction hardened Total depth of hardened surface Effective depth of hardened surface	IDT_____HX* IDE ()_____HX*	IDT_____Ma _____	IDT_____Mi _____	_____ _____	_____ _____

()Values inside the bracket are indicative of the hardness value at which the effective case depth is measured (see 3.2)

*Indicates type of test and load, for example:

a) HV — Vickers test;

b) HV 5 — Vickers test with 5 kg load;

c) HRC — Rockwell C scale; and

d) HRA — Rockwell A scale

ANNEX A

(*Foreword*)

METHODS FOR CASE HARDENING OF STEEL

<table>
<tr><th>Steel</th><th>Process</th></tr>
<tr><td>Direct hardening:</td><td>By differential hardening treatments namely, flame and induction hardening</td></tr>
<tr><td>Carburizing steel:</td><td>By case carburizing and hardening, carbon enrichment of case being obtained by pack carburizing, gas carburizing or carburizing in cyanide bath, or carbonitriding</td></tr>
<tr><td>Nitriding steels:</td><td>By a nitriding process</td></tr>
<tr><td>Carbonitriding:</td><td>During carbonitriding, C and N are absorbed simultaneously in the steel. N increases the hardness of the carburized layer. The process can be carried out in salt bath or gas. The treatment temperature is normally 800 900 °C but both lower and higher temperature can be employed. Carbonitriding in salt bath is the same as cyanide bath hardening. Carbonitriding means carburizing takes gas with simultaneous N pick up. Carburizing takes place by passing gases. Nitrogen in the form of ammonia is supplied direct into the furnace. The composition of the carbonitriding gases are as follows:

Gas — Volume (percent)
N2 — 42
H2 — 38
CO — 20
NH3 — 8</td></tr>
<tr><td></td><td>The surface carbon content is about 0·7 percent. The nitrogen content is 2-4 percent and the effective case depth varies between 0·3 and 0·6 mm. The heat treatment is done for 2-4 hrs depending upon the depth of the case. After treatment, the steel is hardened in the same way as after conventional gas carburizing.</td></tr>
<tr><td>Laser Glazing:</td><td>The laser glazing process uses high power densities, that is, 10^6 to 10^7 W/cm and relatively short dwell times (10^{-8} to 10^{-4} s) to rapidly melt and recast the substrate of suitable material. In order to produce extremely fine-grained structure with improved wear and corrosion resistance. The treatment homogeneity adhesion of overlay coating is applied by electro-chemical technique. Glazed surfaces are produced by means of rapid solidification; the surfaces are non-crystalline (amorphous) and exhibit high hardness value.</td></tr>
</table>

ANNEX B

(*Foreword*)

COMMITTEE COMPOSITION

Metallography and Heat-Treatment Sectional Committee, MTD 22

Organization	*Representative(s)*
Defence Metallurgical Research Laboratory, Ministry of Defence, Hyderabad	Dr Amit Bhattacharjee (***Chairman***) Shri M. Buchi Bhanu (*Alternate*)
Bharat Forge Limited, Pune	Shri Suresh Arangi Shri Sagar Bapat (*Alternate*)
Bharat Heavy Electrical Limited, New Delhi	Shri Vemana Uday Kumar Shri Varun Panwar (*Alternate*)
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Tata Motors Limited, Pune	Shri Pradeep Kulkarni Shri Shailesh Sonwane (*Alternate*)
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Member Secretary

Shri Vishal Kumar Rana,
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